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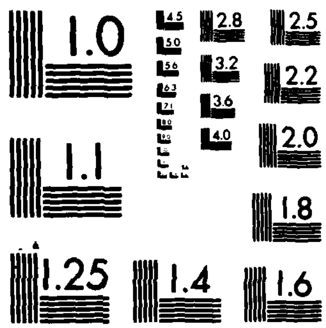

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Laser 85: Optoelektronik

Paul Roman

20 August 1985

U.S. Office of Naval Research, London

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The "Laser 85: Optoelektronik" international congress and trade fair drew several thousand scientists, engineers, and technologists to Munich, West Germany, from 1 through 5 July 1985. This report focuses on research paper presentations dealing with lasers and laser systems, and with lasers and optoelectronics in space technology. It also lists the topics of all sessions and the subject areas of the exhibition.

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CONTENTS

LASER 85: OPTOELEKTRONIK

1 INTRODUCTION

The meeting "Laser 85: Optoelektronik" took place in Munich, West Germany, from 1 through 5 July 1985; it was one in a biennial series (initiated in 1973), subtitled "The Seventh International Congress and International Trade Fair."

About the Meeting

Despite the large number of laser meetings celebrating the 25th anniversary of the first operational laser, the Munich congress drew big crowds: there were over 2000 participants, mostly Europeans, with by far the largest contingent of both speakers and exhibitors coming from Germany. But practically every industrial nation in the world, and also some less developed countries, were well represented. I was impressed by the surprising strength of the delegation from the People's Republic of China, and I was puzzled by the equally numerous Hungarian contingent. The trade fair attracted about 200 exhibitors from 13 countries, and I found it interesting to observe that France, the UK, and the US presented "national exhibitions." It has been rumored that the fair had 8000 visitors (probably including double-counts).

The congress actually consisted of two distinct parts: one devoted to laser physics, technology, optoelectronics, and general-purpose applications; the other (supplemented by the simultaneously held 2nd International Nd:Yag Laser Conference) focusing on medical and biological laser technology. In this report I shall completely ignore the medical component (even though it was substantial, with nearly 100 presentations).

About the Program and This Report

The congress featured 16 plenary-session talks, where leading scientists surveyed the state of art of all major fields. I shall not give a review of these talks, because, even though they often gave a good framework for the research papers to follow, they generally refrained from being specific or evaluative.

The body of the congress consisted of 145 research papers (15 to 20 minutes long). There was no particular emphasis on any special area except for industrial applications; so I select, for illustration, two particular groups of papers: (1) lasers and laser systems, and (2) lasers and optoelectronics in space technology. Of course, even in these areas I will report only a (somewhat arbitrarily) chosen subset of presentations.

In addition to the research papers, there were also two symposia on the role of lasers in world economy and on laser applications in chemistry. I did not attend these and cannot say more about them. There was, further, a ceremonial session where Professor T. Maiman (who in 1960 first succeeded in building a laser) reminisced under the title "Retrospective, and Case Study of the Development of the Laser." Finally, there were five tutorial talks on a simple level, bridging knowledge gaps in the mixed audience. There is no need to report on these talks either. A last general remark: mercifully, there were no poster sessions.

In Appendix A, I give a complete listing of the authors and titles of the plenary session talks and of the tutorials, as well as a thematic listing of all research papers and of the symposia. Since I think that the areas into which the organizers grouped the trade exhibition materials may be indicative of trends in the electro-optic field, I give in Appendix B a listing of the exhibit categories.

Upon request, I will be glad to send copies of the abstracts of the research papers, or of the names of exhibitors in any given area.

The full proceedings of the conference (reproducing the texts of all talks, in every category) will be published by the Münchener Messe und Ausstellungsgesellschaft mbH, in January 1986. Once I receive my copy, I would

be glad to send copies of full texts of selected papers to individual scientists for personal use.

A list of the speakers' institutional affiliations and addresses is also available.

2 SELECTED PRESENTATIONS

Lasers and Laser Systems

These topics were discussed in two full afternoon sessions; the subareas into which the talks were grouped are:

1. Gas lasers, especially excimer and CO_2 lasers
2. Solid state lasers
3. Various other types of special lasers
4. Short pulses
5. Miscellaneous applications.

Two interesting contributions discussed novel excimer lasers. J. Hamish (Institute of Optics, Technical University, West Berlin) described longitudinally pumped excimers. He recalled that such XeF and XeCl lasers emit relatively low-power radiation, but they have a simple preionization mechanism and excellent radiation homogeneity. Recently his group succeeded in obtaining lasing in KrF with a longitudinal gas discharge mechanism. He discussed the performance as a function of partial pressures, tube geometry, and discharge mechanism. His major achievement was that he obtained 10- to 20-ns-long pulses with up to several kilowatts of power.

A related paper, read by Dr. P. Oesterlin (Lambda Physik, Göttingen, West Germany) reported on excimer work focusing on the achievement of high repetition rates (up to 1 kHz) while still maintaining power levels not less than 150 W. His laser medium was XeCl. In fact, the device was based on the modification of a commercially available laser, particularly by enhancing the gas flow velocity in the discharge region. Electrodes were modified too; and by using a magnetic switch control circuit, Oesterlin substantially reduced the load on the thyratron. Similar but less impressive results were obtained with KrF and ArF.

The discussions following these two papers indicated that there is a keen commercial interest in the development of medium-to-high power, high-repetition-rate excimer lasers.

Among the five talks on CO_2 lasers, the first notable paper, by K. Schmidt (Applied Physics Institute, Technical University, Darmstadt, in cooperation with Siemens Tubes, Munich, West Germany), discussed the innovative method of pumping an axial-gas-flow CO_2 laser by ultrahigh frequency (UHF) excitation. Whereas for high-frequency (HF) excitation (up to 100 MHz) simple electrode structures are known to produce good results, for UHF (well over 300 MHz) very complex electrode configurations and coupling schemes had to be invented which allow for an optimal variation of the electric field strength along the discharge volume. The researchers found that the best results could be achieved with a capacity-loaded resonant cavity. They used 500-MHz fields generated by an amplitude modulated master oscillator and an amplifier which gave 2-kW output power. It was possible to obtain synchronous modulation of the laser output power. The major advantage of the UHF excitation versus the HF excitation is precisely the achievement of a much greater modulation width, requiring only a small control power input.

The second interesting paper in the CO_2-group was presented by Professor H. Hügel (Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt [DFVLR] Institute for Technical Physics, Stuttgart, West Germany) who reported about a high-power, axial (longitudinal) gas flow laser with transversal radio frequency excitation. The remarkable feature of the laboratory model developed by the scientists is that it can operate both in the continuous wave mode (with 4-kW output) and in a 100-Hz to 12-kHz pulsed mode when the power output reaches 6 kW. In both cases a closed gas-circulation mechanism was used, and

the "trick" consisted in employing an unstable resonator.

More innovative ideas were discussed by Dr. B. Walter (Institute for Communication Technology, Technical University, Vienna, Austria), who described a TEA-CO_2 laser with preionization that was achieved by specially distributed discharge areas produced by silicon semiconductor electrodes. The distributed resistance of the silicon electrode causes the creation of many arcs between the semiconductor and a metallic anode, which, through their ultraviolet radiation, preionize the space between the main electrodes. The major advantage of using this method is that the preionization occurs in the close neighborhood of the main electrodes. Thus a higher efficiency is achieved (relative to the customary corona discharge methods), and a higher repetition rate can be obtained. On the other hand, this arrangement will work well only with smaller lasers.

Now we turn to notable papers discussing solid state lasers.

J. Eicher (Physics Faculty, University of Kaiserslautern, West Germany) talked about optically pumped solid state lasers that are constructed in the novel format of slab geometry. It is now common (though recent) knowledge that if one uses repeated total reflection in the slab, the effects of mechanical stresses and gradients in the coefficient of refraction (caused by internal heating) are compensated, at least in the first order. The net result is that much higher output energies can be achieved than with conventional rod geometry lasers, maintaining also high-quality radiation. However, the speaker pointed out, it is necessary to find means for compensating temperature gradients in the other two orthogonal directions by sophisticated pumping and cooling, otherwise the automatic compensation in one direction will not be really effective. Eicher described his special arrangement for a Nd:Glass slab laser, where he used combined gas and water cooling of the laser head. Even very high transversal modes showed only negligible thermal perturbations. When 33 percent of the slab volume was utilized, a slope efficiency of 0.5 percent was obtained, even though no attempt was made to optimize the resonator.

In the same area, Professor Wang Shaomin (Department of Physics, Hangzhou University, People's Republic of China) gave a puzzling talk about polished rod lasers. He claimed that face-cooled slab lasers have "pseudo-phase-conjugate properties" and that this concept can be extended to polished rod lasers, even though they have a rather complicated mode structure (as compared to conventional roughened rod lasers). The question-and-answer interchange following the talk did not help my understanding of the subject--it may have been due to the language barrier (second order, my mother toungue not being English either).

New types of tunable solid state lasers were discussed, disappointingly, in only two contributions. K. Mann (Physics Faculty, University of Kaiserslautern, West Germany) reminded the audience that the new alexandrite lasers (tunable between 700 and 800 nm) have a temperature-dependent efficiency. He studied various temperature raising configurations and methods, in conjunction with a 11-cm-long, 0.635-cm-diameter sample. He found that by properly raising the temperature (in one of the experiments by an embedding water jacket, from 20°C to 90°C), the slope efficiency increased from 0.8 to 4 percent, provided the repetition rate was not less than 4 Hz. At the optimal emission with 750-nm wavelength, he produced 16-W average output power when a 1.5-kW pumping power was used.

In the second contribution to this topic, Dr. G. Liftin and his group (Spindler & Hoyer, Göttingen, West Germany) considered rigid, compact, easy to handle, very stable, tunable lasers using more exotic materials than doped alexandrite: he worked with (chromium ion doped) $KZnF_3$, germanium-scandium-gadolinium garnet, or germanium-scandium-aluminium garnet at room temperature. For pumping, red and blue lines

of ion lasers were used, up to 6-W pumping power. Tuning was achieved with a birefringent filter (and sometimes an additional etalon) in the 745 to 825 nm region. In the best cases, 100-mW power levels were obtained, with a 2.8 percent slope efficiency. Remarkably, single mode operation could be achieved without trouble and with very little power loss when a unidirectional ring cavity configuration was adopted. In this case, the line width was as low as 1 MHz.

From the subarea of "special laser types," I will describe three talks.

In the first, Professor H. Welling (Institute for Quantum Optics, University of Hannover, West Germany) reported on his group's efforts to check out earlier Russian claims which intimated that F_2^- type color center materials could produce laser light with good quality even at room temperature. The scientists produced by electron bombardment about $10^{17}cm^{-3}$ F_2^- centers in a host LiF crystal. Indeed, measurements of lifetime and quantum yield indicated that such centers give high optical gain up to room temperature, but this is limited in time by the increasing population of higher metastable energy levels. It was not possible to obtain continuous wave operation at room temperature, but convenient operation under pulsed excitation proved feasible. The LiF_2^- laser was pumped by a Q-switched 1.06-μm Nd:Yag laser. The laser output could be tuned with a prism or a grating in the range 1.07 to 1.16 μm, and had a peak slope efficiency of 10 percent. The output power increased linearly with pump power. Crystal damage occurred at 10-GW/cm^2 pumping power surface density.

The second talk in this subarea concerned itself with the study of wavelength selective semiconductor laser systems, where various types of coupled-cavity GaAlAs or InGaAsP lasers have been coupled to an external resonator. Dr. K.J. Ebeling (now at the Technical University of Braunschweig) reported on the work done at the Third Institute of Physics, University of Göttingen, West Germany. In this research, the external resonator system contained a holographic diffraction grating for wavelength selection. The tuning was achieved by the use of a tiltable mirror. Typical external-resonator lengths were about 10 cm. The researchers found that the emission is single mode, with side-mode suppression ratios of more than 25 dB, and the linewidth is remarkably narrow: less than 500 kHz. Using two mirrors, it was possible to obtain an output of two tuned, narrow, single lines. Mechanical stability and controlled temperature conditions are, of course, crucial for proper operation.

The third talk, by R. Densing (Max Planck Institute for Radio Astronomy, Bonn, West Germany) described an optically pumped, airborne, submillimeter laser system which consisted of a grating-tuned CO_2 or NO_2 pump laser and a plano-plano submillimeter resonator (filled also with CO_2), which operated with metallic and dielectric waveguides. More than 1000 discrete laser lines may be tuned in, in the range of 100 μm to 1 mm, and the system can produce for many of the lines over 10-mW power in continuous mode operation. Since the system has been developed for a US National Aeronautics and Space Administration-supported experiment, many interested colleagues will be already familiar with its performance in interstellar-space molecular spectroscopy.

In the area of short pulses, only one, rather impressive, paper was read: Dr. B. Burghardt (Lambda Physik, Göttingen, West Germany) reported on a new picosecond excimer laser system. (Interestingly, the Lambda Physik group's work was done in cooperation with Zs. Bor, University of Szeged, Hungary.) In this research a commercial XeCl excimer laser (which included an amplifier) was used for pumping a short dye laser, operating at 497 nm. The shortening of the nanosecond pumping pulse was obtained by suppressing the resonator transients. In turn, this was achieved by using an "opto-optical switch," which consists simply of a slantingly positioned second resonator that cuts off the major part of the rapid-rise pulse generated in the dye laser. In this way, pulses of less

than 40 ps were obtained. These then passed through three amplifiers and were frequency doubled, and finally reintroduced into the excimer laser's amplifier. During these operations, further pulse-shortening occurs. In the end, the researchers got 248-nm laser pulses of less than 20-ps duration and yet with an impressive peak power of 1 GW.

In the last area covered by the laser system sessions--i.e., "miscellaneous novel applications"--I found only one which, in my opinion, deserves reporting. (Ironically, the designated speaker was prevented from giving his talk by serious illness.) The research by Professor H.F. Döbele and colleagues (University of Essen, West Germany), done in cooperation with the Lambda Physik establishment in Göttingen, concerned the generation of vacuum ultraviolet radiation by stimulated Raman scattering in hydrogen. While the idea is not entirely new, this work deserves attention because the researchers managed to achieve unusually high power down to less than 120-nm wavelength radiation, with a very simple selection mechanism for bandwidth and tuning. They started with a dye pump source (372 nm), and used it to generate the 6th anti-Stokes line in H_2. Two ArF excimer sections were then used for amplification, yielding about 120-mJ output with less than 0.5-cm^{-1} bandwidth. This radiation is tunable over the ArF* fluorescence line. In a second Raman cell eight additional anti-Stokes components are generated, the shortest having a wavelength of only 118 nm. The output was in the kilowatt range.

Lasers and Optoelectronics in Space Technology

The talks in this area may be divided into three subareas:

1. Communications
2. Ranging, pointing, and tracking
3. Earth observations.

In the first group, almost all the papers sounded exciting; I will report about three.

A. Ulrich (Technical University, Vienna, Austria) in his talk, entitled "Semiconductor Lasers for Coherent Optical Communication Systems" advocated the use of homodyne receiver techniques for communications between satellites. The European Space Agency is now experimenting with laser radiation between 0.8 and 1.3 µm; and it was decided that homodyne receivers will assure smallest error bit-rate (EBR). Theoretical studies showed that minimal EBR, with acceptable losses in sensitivity, require a linewidth on the order of 10 kHz. However, commercially available GaAlAs laser diodes have a much larger line width, on the order of 10 MHz. To bridge this enormous gap, the researchers carry on experimental work aimed at a passive stabilization of the lasers and at improving their spectral stability (by adding a third mirror to the laser resonator). In this way they hope to drastically reduce the linewidth and also to achieve an extremely constant frequency.

Dr. M. Endemann (Battelle Institute, Frankfurt, West Germany) described design considerations and hardware development of a continuous-wave CO_2 waveguide laser, with a wide tuning range (for any selected line) of about 1.4 GhH. This laser is being developed to serve as the local oscillator for an intersatellite laser link. The laser operates at high (up to 500 hP) gas pressure and the resonator's optical length is less than 107 mm. Since I have written a more detailed description of this laser (see Office of Naval Research, London, *Science Newsbrief* 3-41-85), I will not repeat myself here. Instead, I want to report on the paper read by Dr. W. Reiland, which gave a survey of the Battelle-Frankfurt and Technical University, Stuttgart, cooperation concentrating on the transceiver system that will employ the CO_2 waveguide laser I just referred to. The system sponsored by the European Space Agency and the German Federal Ministry for Research and Technology will be part of the Intersatellite Laser Links project. It assumes that high data transfer rates, needed for low Earth orbiting

satellites (LEOs), will necessitate first the transmission of data to a data relay satellite and then to a geosynchronous satellite (GEO). The latter transmits these data either directly to a ground station or, depending on the position of the LEO, via a second laser link to a further GEO relay satellite, which then transmits them to the ground station by microwaves. The satellite-to-satellite laser transceiver system is planned to be able to maintain a data link with more than 1 Gb/s capacity, to have an EBR less than 10^{-8}, and to link up for distances up to 73,000 km. The transmitter will be a CO_2 laser with an electro-optical data modulator and coherent homodyning for detection will be used (see above). Both the transmitter and the receiver will use diffraction-limited optics. Regarding hardware development (in which, besides Battelle and Stuttgart, the Vienna Technical University and the German firm Teldix are involved), major emphasis is given to the optical subsystem, which must handle simultaneously both the received nanowatt infrared signal and the data-modulated transmit-beam in the 1-W power range. Special considerations are given to building high-precision, large, and yet low-weight mirrors, and to constructing polarization-sensitive optical elements, with the goal of minimizing optical cross-talk between the transmitter and receiver channels.

In the second group of talks at this session, one of the papers was also related to the transceiver system mentioned above. Dr. R. Kern (Teldix GmbH, Heidelberg, West Germany) described his research on the pointing, acquisition, and tracking system (PAT) to be used in the intersatellite CO_2 laser link. In order to assure that stringent requirements are met (pointing, with great accuracy, to any location within an entire hemisphere), the PAT is divided into a coarse and a fine pointing assembly. To obtain the control signals for these assemblies in the tracking mode, a conical scan procedure is applied that uses a nutator for orienting the optical system. Because of the great distance between the satellites, the propagation time of the laser beams has to be taken into account! Therefore, a "point-ahead assembly" is being developed. The proper interaction between the various assemblies is assured by appropriate (and involved) control electronics and a microcomputer.

The second talk in this subarea, presented by S. Manhart (Space Division, Messerschmitt-Bölkow-Blohm, Ottobrun, West Germany) reported on the successful design, construction, and test of a self-sustained laser ranging and target tracking system, which consists of a pulsed diode laser range finder, a microprocessor control and data processing system, and a beam deflection unit. The ranging can be done from a 2-m to a 20-km distance, with a resolution varying from 1 mm to 3 km. The acquisition field view is 30°×30°. The acquisition time per frame is 10 seconds. The major result of this research is that it proved the feasibility of laser diode ranging for short- to medium-range sensing distances.

Finally, in the subarea of Earth observation, I will concentrate on two related presentations describing the planned West German-Indian joint research project, called the Monocular Electro-Optical Stereo Scanner (MEOSS) space experiment. Professor F. Lanzl (DFVLR, Institute for Optoelectronics, Oberpfaffenhofen, West Germany) gave an overview. The goals of MEOSS are: (1) to produce threefold stereo line scan images, using a single-objective (monocular) imaging system; and (2) to develop a novel, high-precision, image-correction scheme. The system will use three relatively long lines of charge-coupled devices (CCDs)--3456 pixels in each--in one common focal plane of the CCD camera. It will employ one spectral band, between 570 and 700 nm. It is designed to cope with a 10 Mb/s data rate, and it will give 60-m ground resolution.

In a subsequent talk P. Seige (from the same institute) described his work

in which he tested and selected Texas Instruments model TC-104 CCDs (one-dimensional arrays with 3456 members) that will be used in the MEOSS imaging camera. The commercial devices, after optical scanning and mechanical checks, are subjected to sophisticated electro-optical tests, done at different temperatures, and looking at readout noise, linearity, pixel nonuniformity, dark current, quantum efficiency, optical transfer functions, and so on. Only very few of the supplied CCDs meet the stringent requirements. Apart from its practical use, the testing system also leads to a more thorough understanding of the operation of CCDs in general.

3 SUMMARY

In my opinion, the unusual and most noteworthy aspect of the congress was that the organizers consciously aimed at, and achieved, a very high degree of stimulating interaction between scientists, engineers, and technologists. The discussions were lively and numerous; they illustrated well both these bridge-gapping interactions and the truly multidisciplinary nature of contemporary optoelectronic research and technology. But I should add that quite a number of the questions posed to the speakers were about technological details rather than about basic research aspects--perhaps this reflected the composition of the audience. The well-organized and uncrowded adjacent trade exhibit was praised by many scientist as one where they could get an unusually good insight into trends, and also into the general availability of components and systems needed in their research. This is remarkable because often such exhibits are purely commercial ventures.

The general organization of the meetings was good (despite some annoying overlaps of closely related sessions), and the technical assistance given to the speakers was outstanding and very modern. Most participants look forward to the next meeting in the series, to be held again in Munich, in 1987.

APPENDIX A: LIST OF PRESENTATIONS

Note: All presentations in the medical area have been omitted.

1. Plenary Session Lectures

J. Wolfrum (West Germany): Lasers and chemical reactions.

H. Pummer (US): The status of commercial excimer laser development.

D.C. Hanna (UK): Development of solid state lasers.

A. Sona (Italy): High power lasers and their industrial applications.

J. Hesse (West Germany): Optoelectronic sensor-systems in production technology.

A.F. Carter (US): Lasers and optoelectronics for Earth observation.

C. Baack (West Germany): Development tendencies in optical broadband communications.

B. de Cremoux (France): Perspectives on optoelectronic components.

H. Inaba (Japan): Remote sensing environmental pollution dispersal, using a low loss optical fiber network.

R. Ott (West Germany): Automatic image analysis in industrial environments.

M. Hartmann (West Germany): Optical methods of information storage.

2. Tutorial Talks

K. Gürs (West Germany): Amplification by induced emission.

H. Weber (West Germany): Optical resonators.

H. Herziger (West Germany): Laser material processing.

H. Tiziani (West Germany): Laser metrology techniques.

C. Werner (West Germany): Lasers in environmental measurements.

3. Symposia

Laser applications in chemistry (Chair: F. Dörr, West Germany).

Lasers and the economy (Chair: J. Pabst, West Germany).

4. Research Paper Presentation Sessions

Laser components.

Lasers and optoelectronics in metrology (three sessions).

Laser systems, part 1 (gas, excimer, and CO_2 lasers; solid state lasers).

Laser systems, part 2 (diode, infrared and He-Ne lasers; short pulses; applications).

Lasers in material processing (four sessions).

Optoelectronic signal transmission.

Lasers and optoelectronics in space technology.

Lasers and optoelectronics in environmental measurement techniques (two sessions).

Miscellaneous contributions.

APPENDIX B: SUBJECT AREAS OF THE TRADE FAIR

1. Complete laser systems
2. Metrology and test equipment
3. Special lasers
4. Mechanical and optical laser components and accessories
5. Light detectors and radiation detectors
6. Light and radiation sources; displays
7. Optical components
8. Modulators and deflectors
9. Optoelectronic imaging devices
10. Electro-optic analytic systems
11. Optical materials and accessories
12. Optical signal transmission
13. Instrumentation and calibration equipment
14. Cameras and accessories
15. Holographic equipment
16. Protective equipment
17. Vacuum and gas handling equipment
18. Miscellaneous

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